Proceeding

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Concordance between the indirect $\dot{V}O_{2max}$ value estimated through the distance in Yo-Yo intermittent recovery test level 1 and the direct measurement during a treadmill protocol test in elite youth soccer players

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ABSTRACT

The main aim of this study was to evaluate the concordance between the indirect $\dot{V}O_{2max}$ value estimated by the distance achieved in the Yo-Yo intermittent recovery test level 1 (YYIR1) and the direct measurement during a treadmill protocol test (TP) in elite youth soccer players. Methods: Fourteen elite under 20 year's old soccer players from a first division soccer club were evaluated. Test were performed one week apart. In both tests $\dot{V}O_2$, was measured with an ambulatory gas exchange measurement. YYIR1 estimated $\dot{V}O_{2max}$ was calculated using the equation described by Bangsbo et al. (2008) and in TP was calculated using American College of Sport Medicine equation. Results: Lin´s concordance correlation coefficient between direct $\dot{V}O_{2max}$ in TP and estimated $\dot{V}O_{2max}$ in YYIR1=0.271 (poor concordance). Conclusions: The poor concordance between direct and indirect $\dot{V}O_{2max}$ measurements in TP and YYIR1, indicated that in an elite population both

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test, are not good indirect predictors of $\dot{V}O_{2max}$, reached in those tests using current predictive equations. The YYIR1 is well established as a performance-relevant test in elite players, but our data suggests that due to its poor concordance with imprecise estimation of $\dot{V}O_{2max}$, which should be measured directly if this variable is of specific interest. **Key words**: INTERMITTENT EXERCISE, ADOLESCENT, SOCCER PLAYERS, OXYGEN CONSUMPTION, YO-YO INTERMITTENT RECOVERY 1 TEST.

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INTRODUCTION

Soccer performance depends upon a variety of tactical, technical, physical and physiological factors (Stølen et al., 2005) and is characterized by direction changes, sprinting, tackling and jumping (Wisloff et al., 1998). Elite level outfield players, cover approximately 10-12 km during a match, and on average every 90 seconds sprint for approximately 2-4 seconds (Bangsbo et al., 1991), demostrating the relevance of both aerobic and anaerobic fitness (Castagna et al., 2006).

High levels of maximal oxygen consumption ($\dot{V}O2max$) are reported (58-65 ml. min-1. kg) in young elite outfield players (Strøyer et al., 2004) and $\dot{V}O2max$ is correlated with a number of aspects of on-pitch performance such as distance covered, repeated sprint ability and the ability to recovery from repeated sprints (Jones et al., 2013; Gharbi et al., 2015). Laboratory protocols involving the direct measurement of gas exchange during continuous treadmill running at progressively higher intensities to exhaustion are considered the gold standard for aerobic fitness assessment (Castagna et al., 2006; Aziz et al., 2005). However, the validity of a test also depends on its specificity to the sport (Krustrup et al., 2003), and given the intermittent and multi-directional nature of soccer, tests which reflect this activity have been proposed as an alternative to straight-line continuous laboratory treadmill protocols (TP). The Yo-Yo intermittent recovery test level 1 (YYIR1) is one such protocol which consists of repeated 2 x 20m shuttle runs at progressively increasing speed, with 10-second active rest periods between shuttles (Bangsbo, 1994). This test therefore provides important information on the capacity to perform intense intermittent exercise, which includes repeated decelerations and changes of direction that are characteristic of soccer match play (Bangsbo et al., 2008), and also has a significant association with sprint time and time spent in high intensity activities (Rebelo et al., 2014).

In addition to characterizing soccer-specific work capacity, the YYIR1 distance has also been used to estimate $\dot{V}O2max$ using a regression equation (Bangsbo et al., 2008) and several studies report a correlation between $\dot{V}O2max$ estimated during the field test and directly measured $\dot{V}O2max$ achieved during a TP (Castagna et al., 2006; Aziz et al., 2005; Metaxas et al., 2005).

While the degree of association between the two methods, is often represented by the correlation between methods (Aziz et al., 2005; Castagna et al., 2006), when assessing the capacity of an indirect test in the estimation of physiological variable, it is important to also consider the accuracy and precision of that estimation, quantified by its concordance (Lin, 1989; Lin, 2000) and visualized using a Bland-Altman plot (Altman and Bland, 1983; Bland and Altman, 1986). To our knowledge, these factors have not been evaluated with respect to YYIR1 and $\dot{V}O2max$ in elite male soccer players. Therefore, the principle aim of the present study was to evaluate the concordance between the indirect $\dot{V}O2max$ value estimated through the distance reached in YYIR1 and the direct measurement during a TP in a sample of elite youth soccer players.

METHODS

Participants

Fourteen elite (14) under-20 years old soccer players from a first division soccer club of the Colombian Professional Soccer League were voluntarily evaluated. All the subjects were players of the squad of the champion team of the Colombian National Professional League 2015 and six players, at the time of the test, were called to represent their country in the national team; the goalkeepers were included in the study. All trained generally six times per week, in daily sessions of between 90 to 120 minutes, plus at least one official match, and they had belonged to the professional team for at least one year. All had previous experience in the test and this study was carried out as part of the training program under the direction of the coaches and with the approval of the club executives. They were informed verbally and writing about the possible risks and benefits, and all signed an informed consent. This study was carried out under the codes of ethics of the Declaration of Helsinki and was approved by the Institutional Ethics Committee.

The measured variables were anthropometric variables age, body mass and height and physiological variables direct and indirect $\dot{V}O_{2max}$ in YYIR1 and TP, maximal heart rate (HR_{max}) and distance covered in YYIR1.

Treadmill protocol test (TP)

Players warmed-up on the treadmill (Trackmaster TMX 425®) for 10 min at 5.0 km. h^{-1}. The test started at 7.0 km. h^{-1} with two degrees of gradient, the speed was increased by 1.0 $km \cdot h^{-1}$ every minute, until the player reached volitional exhaustion. This was followed by 3 min of active recovery at 5.0 km. h^{-1} (Castagna et al., 2006). All laboratory tests were performed in the morning over two consecutive days at morning.

Yo-Yo intermittent recovery 1 test (YYIR1)

The YYIR1 was performed following the same warm-up described for the treadmill test. The test involves running 20 m shuttles at a progressively increasing speed controlled by audio bleeps. After every second 20 m shuttle, there is a 10 second active recovery period, during which players walk. The test ended when the subject was unable to complete the distance at the assigned speed on two consecutive occasions (Bangsbo et al., 2008). The test was followed by 3 mins of active recovery. All field tests were performed in the morning over two consecutive days.

Procedures

The tests were carried out in January, during preseason. The subjects were instructed to maintain their habitual nutritional intake the day before the test, also asked to refrain from consuming food and beverages (other than water) for 2 hours before each testing session, with a sleep period of at least six hours, without consumption of stimulants or alcoholic beverages; they were instructed not to perform intense physical activity in the last 24 hours. Before the players performed the tests, they were told that they should try their best and verbally encouraged them to run as long as possible.

All players attended the university laboratory to perform a $\dot{V}O2max$ TP. YYIR1 was performed on a pitch at the club's training ground, 5-7 days after the TP at the same time of day and with similar environmental conditions, air temperature ranged from 21ºC to 26ºC, and relative humidity were ranged from 55% to 60% in all the tests. Weight records were made on a Tanita BC-585F FitScan Body Composition Monitor®, and size on a CE 0123 UK® DRY stadiometer.

In both the field and laboratory test $\dot{V}O_2$ was measured with a portable telemetric device (Cosmed K4b$^{2®}$). Achievement of $\dot{V}O_{2max}$ was considered as the attainment of at least one following criteria; a respiratory exchange ratio above 1.10 or plateau in $\dot{V}O_2$ despite increasing speeds. Before each test, the device was calibrated in accordance with the manufacturer's recommendations. Heart rate was recorded using a Polar RS800CX® (Polar, Finland). Estimated $\dot{V}O_{2max}$ in the YYIR1 was calculated using the equation described by Bangsbo et al. (2008), and estimated $\dot{V}O_{2max}$ in treadmill test was calculated using the American College of SPORTS MED equation (ACSM) (American College of sports medicine, 2013).

Statistical analysis

SPSS (20.0 for windows) was used for all statistical analyses. Normality was verified using the Shapiro-Wilk test. Comparisons between physiological variables in the tests was performed using paired samples *t*-test. Pearson´s product-moment correlations were used to examine the relationships between HR_{max}, direct and indirect values $\dot{V}O_{2max}$ in YYIR1 and TP and distance covered in YYIR1 and $\dot{V}O_{2max}$ in YYIR1 and TP.

The Bland-Altman limits-of-agreement method was used to examine individual differences between HR_{max}, direct and indirect values $\dot{V}O_{2max}$ in YYIR1 and TP. Significance was set at 0.05 ($p \leq 0.05$). The Lin´s concordance correlation coefficient (CCC) was used to examine the relationships between HR_{max}, direct and indirect values $\dot{V}O_{2max}$ in YYIR1 and TP.

The CCC was interpreted as follows: > 0.99, almost perfect strength of agreement; 0.95 to 0.99, substantial strength of agreement; 0.90 to 0.95 moderate strength of agreement; < 0.90 poor strength of agreement (McBride, 2005).

RESULTS

Table 1 shows anthropometric data and physical characteristics of all subjects.

Table1. Anthropometric characteristics of subjects

Variables (n = 14)	(Mean ± SD)
Age (years)	18.4 ± 1
Body Mass (kg)	72.4 ± 4.2
Height (cm)	180 ± 7

The mean and SD of the physiological and performance variables are shown in Table 2. There were significant differences between TP direct and indirect $\dot{V}O_{2max}$ ($p = 0.002$), and between YYIR1 and TP indirect $\dot{V}O2max$ ($p < 0.009$). No significant differences were observed in the other physiological variables (Table 2).

Table2. Physiological responses in treadmill and field test

Variables	YYIR1 (Mean ± *SD* values)	TP (Mean ± *SD* values)
Direct $\dot{V}O_{2max}$ (ml. $kg^{-1}.min^{-1}$)	54.9 ± 6.6*	55.5 ± 4.2*
Indirect $\dot{V}O_{2max}$ (ml. kg^{-1}. min^{-1})	56.9 ± 1.6*	60.0 ± 3.9
HRmax (b·min-1)	188.8 ± 5.8	188.6 ± 6
Distance covered (m)	2451.4 ± 195.6	

**significantly different with indirect $\dot{V}O_{2max}$ in TP ($p < 0.05$)*

There was a significant correlation in direct $\dot{V}O2max$, in the TP and in the YYIR1 test, direct and indirect $\dot{V}O_{2max}$ in YYIR1 and between the distance covered in YYIR1 and $\dot{V}O_{2max}$ (Table 3). However, there was a poor agreement between the direct and indirect measurement of $\dot{V}O_{2max}$ and HR_{max} in the two tests (Table 3).

Table3. Pearson correlation coefficients and CCC in YYIR1 and TP

Variables	Pearson correlation	CCC
Direct $\dot{V}O_{2max}$	$r = 0.71$ ($p = 0.004$) †	0.642*
Direct-Indirect $\dot{V}O_{2max}$ YYIR1	$r = 0.65$ ($p = 0.010$) †	0.276*
Direct-Indirect $\dot{V}O_{2max}$ TP	$r = 0.38$ ($p = 0.177$)	0.229*
Indirect $\dot{V}O_{2max}$	$r = 0.31$ ($p = 0.277$)	0.142*
Indirect $\dot{V}O_{2max}$ YYIR1- Direct $\dot{V}O_{2max}$ TP	$r = 0.44$ ($p = 0.111$)	0.269*
Indirect $\dot{V}O_{2max}$ TP- Direct $\dot{V}O_{2max}$ YYIR1	*$r = 0.56$ ($p = 0.034$)* †	0.345*
HR_{max}	$r = 0.36$ ($p = 0.209$)	0.357*
Distance YYIR1-Direct $\dot{V}O_{2max}$ YYIR1	$r = 0.65$ ($p = 0.010$) †	
Distance YYIR1-Direct $\dot{V}O_{2max}$ TP	$r = 0.44$ ($p = 0.11$)	

* *Poor strength of agreement.*

† *Significant Pearson product-moment correlation coefficient*

Figure 1 to 7 shows all the Bland-Altman plot between variables.

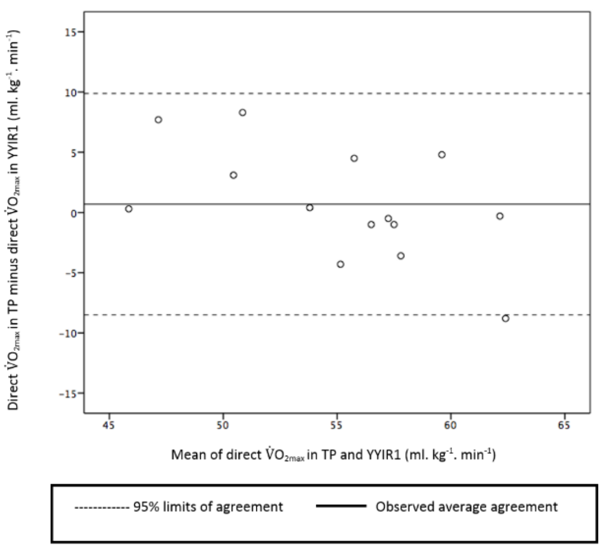

Figure 1. Bland-Altman difference plot direct $\dot{V}O_{2max}$ in TP and YYIR1 (n=14). Bias 0.68; limits of agreement, 9.8 -8.5 ml. kg^{-1}. min^{-1}

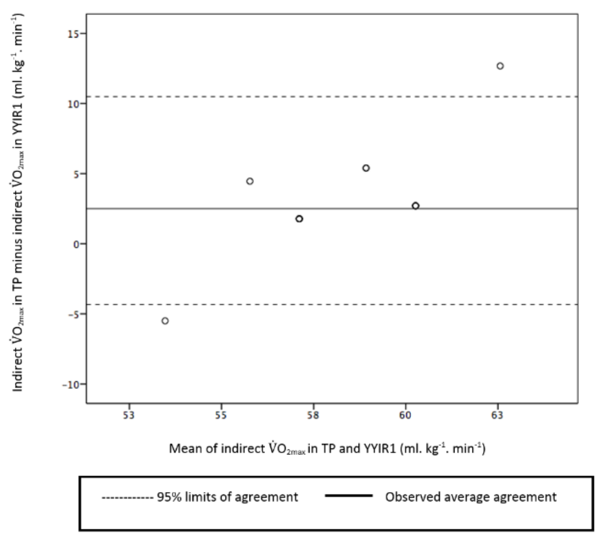

Figure 2. Bland-Altman difference plot indirect $\dot{V}O_{2max}$ in TP and YYIR1 (n=14). Bias 3.07; limits of agreement, 10.4 -4.33 ml. kg^{-1}. min^{-1}

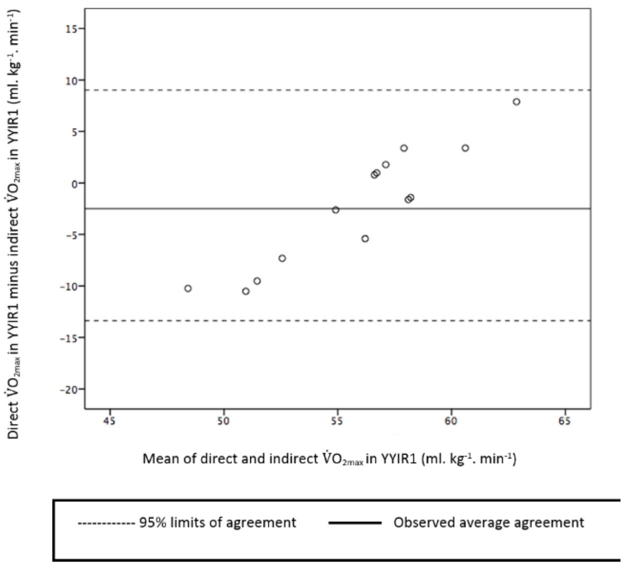

Figure 3. Bland-Altman difference plot direct and indirect $\dot{V}O_{2max}$ in YYIR1 test (n=14). Bias -2.1; limits of agreement, 9 -13.3 ml. kg^{-1}. min^{-1}

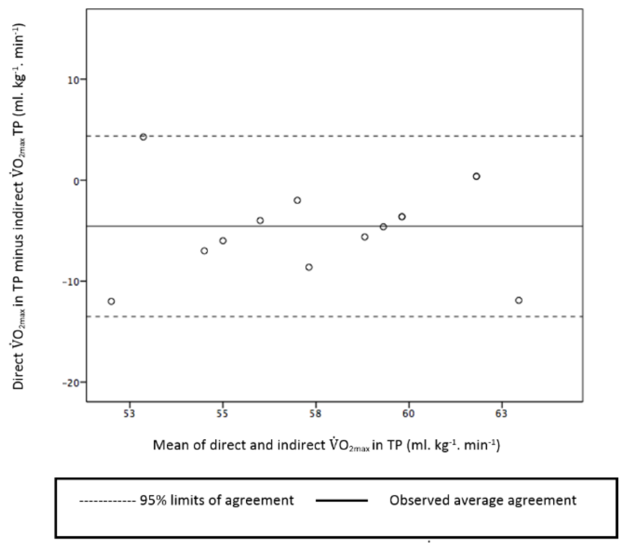

Figure 4. Bland-Altman difference plot direct and indirect $\dot{V}O_{2max}$ in TP test (n=14). Bias -4.5; limits of agreement, 4.3 -13.5 ml. kg^{-1}. min^{-1}

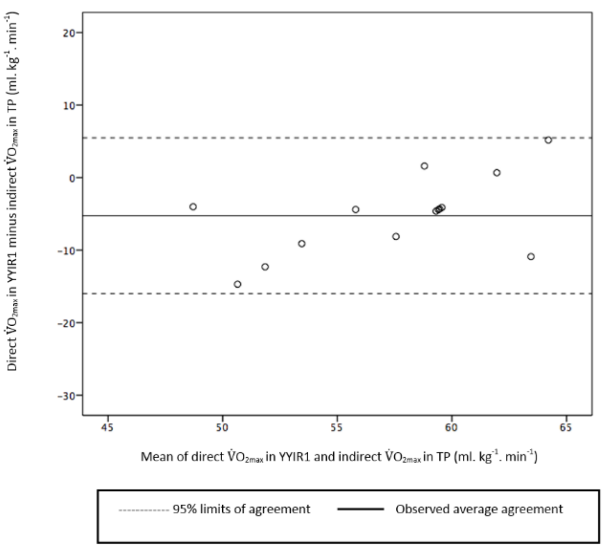

Figure 5. Bland-Altman difference plot direct $\dot{V}O_{2max}$ in YYIR1 and indirect $\dot{V}O_{2max}$ in TP (n=14). Bias -5.25; limits of agreement, 5.48 -15.99 ml. kg^{-1}. min^{-1}

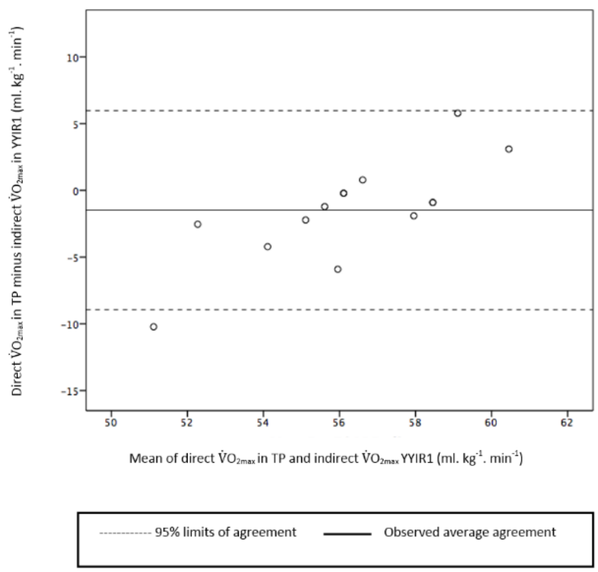

Figure 6. Bland-Altman difference plot direct $\dot{V}O_{2max}$ in TP and indirect $\dot{V}O_{2max}$ in YYIR1 (n=14). Bias -1.48; limits of agreement, 5.96 -8.94 ml. kg^{-1}. min^{-1}

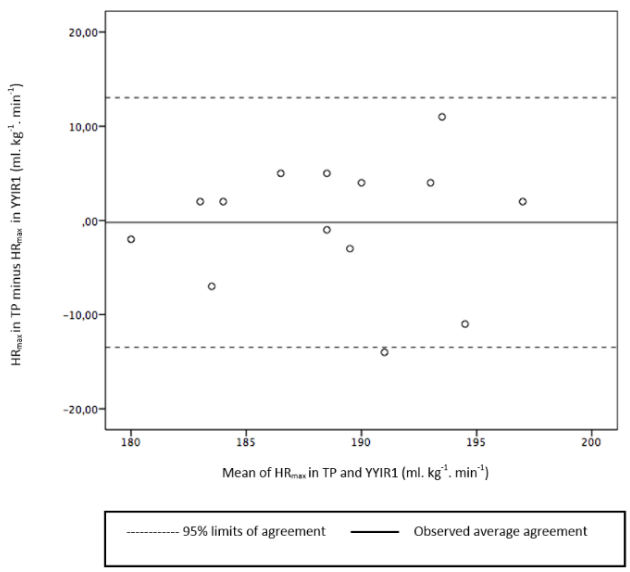

Figure 7. Bland-Altman difference plot direct in HR_{max} in TP and YYIR1 (n=14). Bias -0.21; limits of agreement, 13.03 –13.46 ml. kg^{-1}. min^{-1}

DISCUSSION

To our knowledge, the present study is the first to evaluate concordance between the indirect $\dot{V}O_{2max}$ value estimated through the distance in YYIR1 and the direct measurement during a TP in elite youth soccer players. We also evaluate the concordance between direct measurements of $\dot{V}O_{2max}$ and estimated value achieved during the YYIR1 and TP, respectively.

The average distance YYIR1 covered in our sample was 2451 m, similar to the 2420 m reported in elite male players by Bangsbo et al. (2008) and substantially higher than the 1640 m observed in sub-elite young soccer player (Deprez et al., 2014). Mean TP values in the present sample were 55 mm. kg. min^{-1} (in TP), which are within the expected range for elite football players, which range from 50 to 75 mm. kg. min^{-1}, (Stølen et al., 2005), and those reported for youth players, which are below 60 mm. kg. min^{-1} (Helgerud et al., 2001).

We found no correlation between the distance covered during the YYIR1 test and directly measured $\dot{V}O_{2max}$ assessed using the TP. A number of studies have also evaluated this relationship amongst different populations (Castagna et al., 2006; Krustup et al., 2003; Krustup et al., 2005; Martinez-Laguna and Hartmann, 2014). Using a TP which only differed from the present protocol with respect to the percentage incline used (1%), Castagna et al. (2006) also found no correlation between $\dot{V}O_{2max}$ and YYIR1 distance in amateur male soccer players. On the other hand, in female players Martínez-Laguna and Hartmann (2014) found correlation (r = 0.70; p = < 0.05), but with a large dispersion of the data, noticing a large variation in the YYIR1 distance covered at a given directly measured $\dot{V}O_{2max}$ value (Martinez-Laguna and Hartmann, 2014). In contrast, Krustrup et al. (2003) observed a significant correlation between the two variables (r = 0.71, p <0.05) in a sample of physically active subjects. Both the homogeneity and profile of our sample - compared with the non-elite, physically active population in Krustrup's study are factors which may explain the lower degree of association between the distance traveled in the YYIR1 and $\dot{V}O_{2max}$ directly measured in the laboratory in the present study.

In agreement with the superior development of soccer-specific work capacity in high level players, and confirming the ability of the YYIR1 to quantify via the distance covered, the player's capacity to perform intermittent high intensity activity which involves changes of direction. The YYIR1 was specifically designed to assess the aerobic-anaerobic performance of soccer players and not as a general field test for the assessment of aerobic performance (Castagna et al., 2006). Poor association with direct $\dot{V}O_{2max}$ value in TP, may reflect the greater influence of other physical characteristics developed during soccer training and competition on test performance in those with a greater soccer-specific training background.

Ahmaidi et al. (1992), suggest that the differences in the values obtained in the different tests could be related to biomechanical factors and the energy expenditure efficiency, possibly because of the recruitment pattern of fibers, being more efficient for a specific intensity task, a higher recruitment of type I fibers than type II (Mauger and Sculthorpe, 2012).

However, in a population not specifically trained in these activities, performance in a test such as YYIR1 may relate more to aerobic capacity, and potentially to overall level of fitness, particularly in a population with a wide range of $\dot{V}O_{2max}$ values, thereby tending to improve the association between the two variables (Castagna et al., 2006, Chamari et al., 2005).

Comparison between physiological variables during the TP and YYIR1

Despite the poor association between YYIR1 distance and $\dot{V}O_{2max}$ directly measure in TP, no significant difference between the HR_{max} and direct $\dot{V}O_{2max}$ values achieved during the two tests was found, which concurs with a number of previous studies (Aziz et al., 2005; Krustrup et al., 2003; Martinez-Laguna and Hartmann, 2014). Furthermore, Martinez-Laguna and Hartmann (2014) also observed a significant correlation between directly measured $\dot{V}O_{2max}$ in the YYIR1 and a TP ($r = 0.83$; $p < 0.05$), similar to that observed in the present study ($r = 0.71$; $p = 0.004$). This suggests that despite the distinct characteristics of the two tests; the continuous and straight line nature of the TP, with progressive increases in intensity, compared to the intermittent actions, with changes in direction and intensity of the YYIR1, the overall aerobic demand in the YYIR1 and TP tests is similar.

Despite this, would be an error make comparisons between the values obtained directly in a TP, with the subsequent performance in YYIR1, without direct measurement of oxygen uptake in the latter, due to the difference in the type of effort performed in both tests (Castagna et al., 2006). For example, Aziz et al. (2005), compared two protocols of continuous and intermittent type tests and reported that between both tests only shared a common variance of 40%, which indicates that the performance in any of the tests may not be interchangeable. Likewise, Lemmink et al. (2004) found that the test that was able to clearly distinguish the different levels of sports performance of soccer players was intermittent protocol.

There was also a significant correlation between the directly measured and estimated $\dot{V}O_{2max}$ in the YYIR1 ($r = 0.66$; $p = 0.010$). In contrast, the direct and indirect values in the TP estimated were not significantly correlated ($r = 0.38$; $p = 0.177$). However, despite this acceptable degree of correlation in, we found a poor concordance in both. The CCC, provides a measure not only of the magnitude of the agreement between two methods, but also it also aggregates random and the systematic bias. Because of this, it is considered a better tool to determine the concordance in the value obtained by two different methods (Lin, 1989; Lin, 2000) than the *r* value generated in correlation analysis which only represents the mean magnitude of association between the tests. Nonetheless, as the CCC is an aggregate method and it does not identify which of the two types of bias have the largest impact on the degree of accuracy, is therefore combined with a graphical analysis using the Bland and Altman method (Altman and Bland, 1983; Bland and Altman, 1986).

Therefore, in higher level athletes other type of field tests which involve continuous effort, such as the Yo-Yo Endurance Test (Castagna et al., 2006), Cooper 12-minute-run test (Cooper, 1968) or 20-m-shuttle-run test (Leger and Lambert, 1982), can be more accurate to estimate $\dot{V}O_{2max}$, if that is the objective, in soccer players. On the other hand, the importance of $\dot{V}O_{2max}$ in football has been questioned (Krustrup et al., 2003) and as such the changes of direction and the intermittent intensity present in the YYIR1, specific to the movement patterns of soccer make this test a more relevant fact to evaluate performance in higher level players, despite this lack of concordance with $\dot{V}O_{2max}$ (Castagna et al., 2006, Stølen et al., 2005). In accordance with this YYIR1 distance covered is associated with football performance, for example, Mohr et al. (2003) reported that the amount of high intensity activity that a player is capable of performing is one of the variables that separates players with different levels of sports performance.

The principle limitation of the present study is sample size, related to the difficulty of obtain consent for participation from both coaches and players in an elite team sport environment where the time consuming nature of direct $\dot{V}O_{2max}$ evaluations are problematic. The lack of control of environmental conditions in the YYIR1, could be a limitation, because we do not have a closed soccer field with controlled conditions, despite this, the physiological responses were similar to those reported in literature. Finally the lack of randomness in the realization of the tests, since for logistical reasons the TP's were made first and finally all the YYIR1.

Practical applications

Distance covered in the YYIR1 is reported to reflect capacity to perform soccer-specific intermittent activity and discriminate performance levels and on that basis useful in assessing elite soccer players. However, in elite male players, it appears that the use of current regression equations based on performance in the YYIR1 will provide inaccurate estimates of $\dot{V}O_{2max}$. Therefore, if $\dot{V}O_{2max}$ is desired it should be measured directly in a TP and should not be estimated based on performance in the YYIR1 or in the TP. Future work may establish an elite player-specific regression equation to improve this estimation and enable both soccer-specific work capacity and $\dot{V}O_{2max}$ to be determined using this single field test.

CONCLUSIONS

We found that for the accurate determination of maximal oxygen consumption in elite soccer players, it is necessary to use direct measurement in a TP, as a field tests with intermittent actions such as YYIR1 and regression equations for the prediction of these values are inaccurate in the prediction of $\dot{V}O_{2max}$, despite being well correlated.

REFERENCES

Ahmaidi, S., Collomp, K., Caillaud, C., & Prefaut, C. (1992). Maximal and functional aerobic capacity as assessed by two graduated field methods in comparison to laboratory exercise testing in moderately trained subjects. INT J SPORTS MED, 13(03), 243-248. https://doi.org/10.1055/s-2007-1021261

Altman, D. G., & Bland, J. M. (1983). Measurement in medicine: the analysis of method comparison studies. The statistician, 307-317. https://doi.org/10.2307/2987937

American College of Sports Medicine. (2013). ACSM's guidelines for exercise testing and prescription. Lippincott Williams & Wilkins.

Aziz, A. R., Tan, F. H., & Teh, K. C. (2005). A pilot study comparing two field tests with the treadmill run test in soccer players. J SPORT SCI MED, 4(2), 105.

Bangsbo, J. (1994). Fitness training in football: a scientific approach. August Krogh Inst., University of Copenhagen.

Bangsbo, J., Iaia, F. M., & Krustrup, P. (2008). The Yo-Yo intermittent recovery test. SPORTS MED, 38(1), 37-51. https://doi.org/10.2165/00007256-200838010-00004

Bangsbo, J., Nørregaard, L., & Thorsoe, F. (1991). Activity profile of competition soccer. CAN J SPORT SCI, 16(2), 110-116.

Bland, J. M. and D. G. Altman. 1986. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet I: 307–310. https://doi.org/10.1016/S0140-6736(86)90837-8

Castagna, C., Impellizzeri, F. M., Chamari, K., Carlomagno, D., & Rampinini, E. (2006). Aerobic fitness and Yo-Yo continuous and intermittent tests performances in soccer players: A correlation study. J STRENGTH COND RES, 20(2), 320-325. https://doi.org/10.1519/R-18065.1

Chamari, K., Moussa-Chamari, I., Boussaidi, L., Hachana, Y., Kaouech, F., & Wisløff, U. (2005). Appropriate interpretation of aerobic capacity: allometric scaling in adult and young soccer players. BRIT J SPORT MED, 39(2), 97-101. https://doi.org/10.1136/bjsm.2003.010215

Cooper, K. H. (1968). A means of assessing maximal oxygen intake: correlation between field and treadmill testing. JAMA, 203(3), 201-204. https://doi.org/10.1001/jama.1968.03140030033008

Deprez, D., Coutts, A. J., Lenoir, M., Fransen, J., Pion, J., Philippaerts, R., & Vaeyens, R. (2014). Reliability and validity of the Yo-Yo intermittent recovery test level 1 in young soccer players. J SPORT SCI, 32(10), 903-910. https://doi.org/10.1080/02640414.2013.876088

Gharbi, Z., Dardouri, W., Haj-Sassi, R., Chamari, K., & Souissi, N. (2015). Aerobic and anaerobic determinants of repeated sprint ability in team sports athletes. BIOL SPORT, 32(3), 207. https://doi.org/10.5604/20831862.1150302

Helgerud, J., Engen, L. C., Wisløff, U., & Hoff, J. (2001). Aerobic endurance training improves soccer performance. MED SCI SPORT EXER, 33(11), 1925-1931. https://doi.org/10.1097/00005768-200111000-00019

Jones, R. M., Cook, C. C., Kilduff, L. P., Milanović, Z., James, N., Sporiš, G., ... & Vučković, G. (2013). Relationship between repeated sprint ability and aerobic capacity in professional soccer players. SCI WORLD J, 2013. https://doi.org/10.1155/2013/952350

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., & Bangsbo, J. (2003). The yo-yo intermittent recovery test: physiological response, reliability, and validity. MED SCI SPORT EXER, 35(4), 697-705. https://doi.org/10.1249/01.MSS.0000058441.94520.32

Krustrup, P., Mohr, M., Ellingsgaard, H. E. L. G. A., & Bangsbo, J. (2005). Physical demands during an elite female soccer game: importance of training status. MED SCI SPORT EXER, 37(7), 1242. https://doi.org/10.1249/01.mss.0000170062.73981.94

Leger, L. A., & Lambert, J. (1982). A maximal multistage 20-m shuttle run test to predict $ $\dot V $ $ O2 max. EUR J APPL PHYSIOL O, 49(1), 1-12. https://doi.org/10.1007/BF00428958

Lemmink, K. A. P. M., Verheijen, R., & Visscher, C. (2004). The discriminative power of the Interval Shuttle Run Test and the Maximal Multistage Shuttle Run Test for playing level of soccer. J SPORT MED PHYS FIT, 44(3), 233.

Lin, L. I. (1989). A concordance correlation coefficient to evaluate reproducibility. Biometrics 45: 255–268. https://doi.org/10.2307/2532051

Lin, L. I. (2000). A note on the concordance correlation coefficient. Biometrics 56: 324–325.

Martínez-Lagunas, V., & Hartmann, U. (2014). Validity of the Yo-Yo Intermittent Recovery Test Level 1 for direct measurement or indirect estimation of maximal oxygen uptake in female soccer players. INT J SPORT PHYSIOL, 9(5). https://doi.org/10.1123/ijspp.2013-0313

Mauger, A. R., & Sculthorpe, N. (2012). A new VO2max protocol allowing self-pacing in maximal incremental exercise. BR J SPORTS MED, 46(1), 59-63. https://doi.org/10.1136/bjsports-2011-090006

Metaxas, T. I., Koutlianos, N. A., Kouidi, E. J., & Deligiannis, A. P. (2005). Comparative study of field and laboratory tests for the evaluation of aerobic capacity in soccer players. J STRENGTH COND RES, 19(1), 79-84.

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. J SPORT SCI, 21(7), 519-528. https://doi.org/10.1080/0264041031000071182

Rebelo, A., Brito, J., Seabra, A., Oliveira, J., & Krustrup, P. (2014). Physical match performance of youth football players in relation to physical capacity. EUR J SPORT SCI, 14(sup1), S148-S156. https://doi.org/10.1080/17461391.2012.664171

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer. SPORTS MED, 35(6), 501-536. https://doi.org/10.2165/00007256-200535060-00004

Strøyer, J., Hansen, L., & Klausen, K. (2004). Physiological profile and activity pattern of young soccer players during match play. MED SCI SPORT EXER, 36(1), 168-174. https://doi.org/10.1249/01.MSS.0000106187.05259.96

Wisloeff, U., Helgerud, J., & Hoff, J. (1998). Strength and endurance of elite soccer players. MED SCI SPORT EXER, 30, 462-467. https://doi.org/10.1097/00005768-199803000-00019